Sediment and Terrestrial Toxicity and Bioaccumulation of Nano Aluminum Oxide

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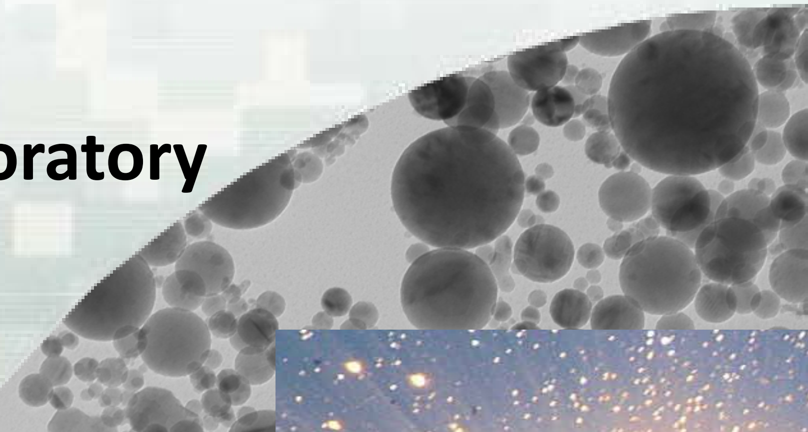

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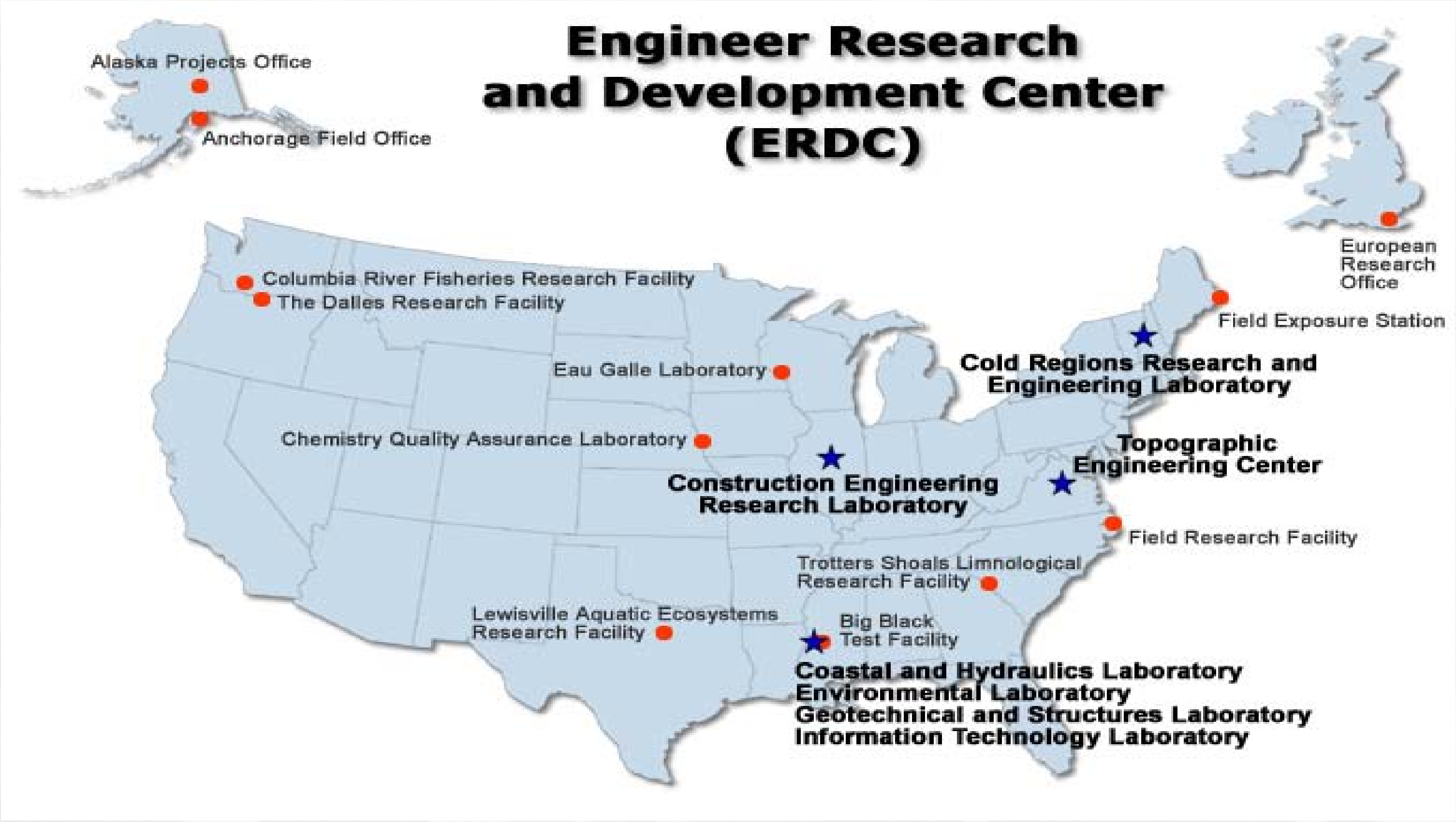
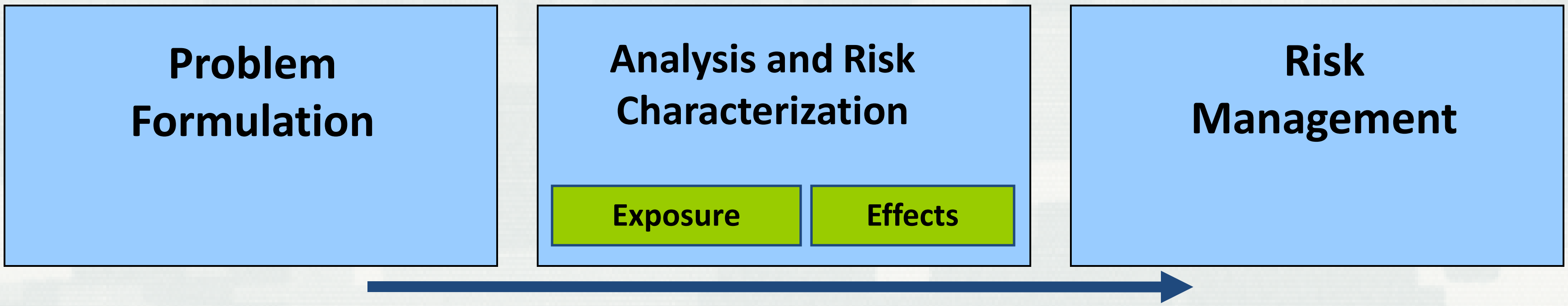


Risk Assessment of Nanomaterials



- Identify and quantify environmental attributes of nanomaterials
  - Sources?
  - Fate and transport mechanisms?
  - Likely exposure scenarios?
  - Biological effects?

- Characterize physical / chemical interactions between engineered nanomaterials and environmental media

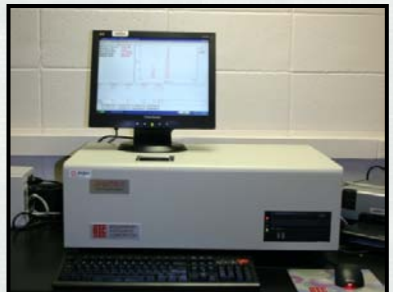
GOAL → Establish approaches for predicting relevant characteristics associated with toxicity and environmental impacts(persistence, fate, toxicology)

ERDC Nanomaterials Risk Research Cluster

- Material characterization
- Fate and transport
- Ecotoxicology
- Computational chemistry
- Risk and decision analysis



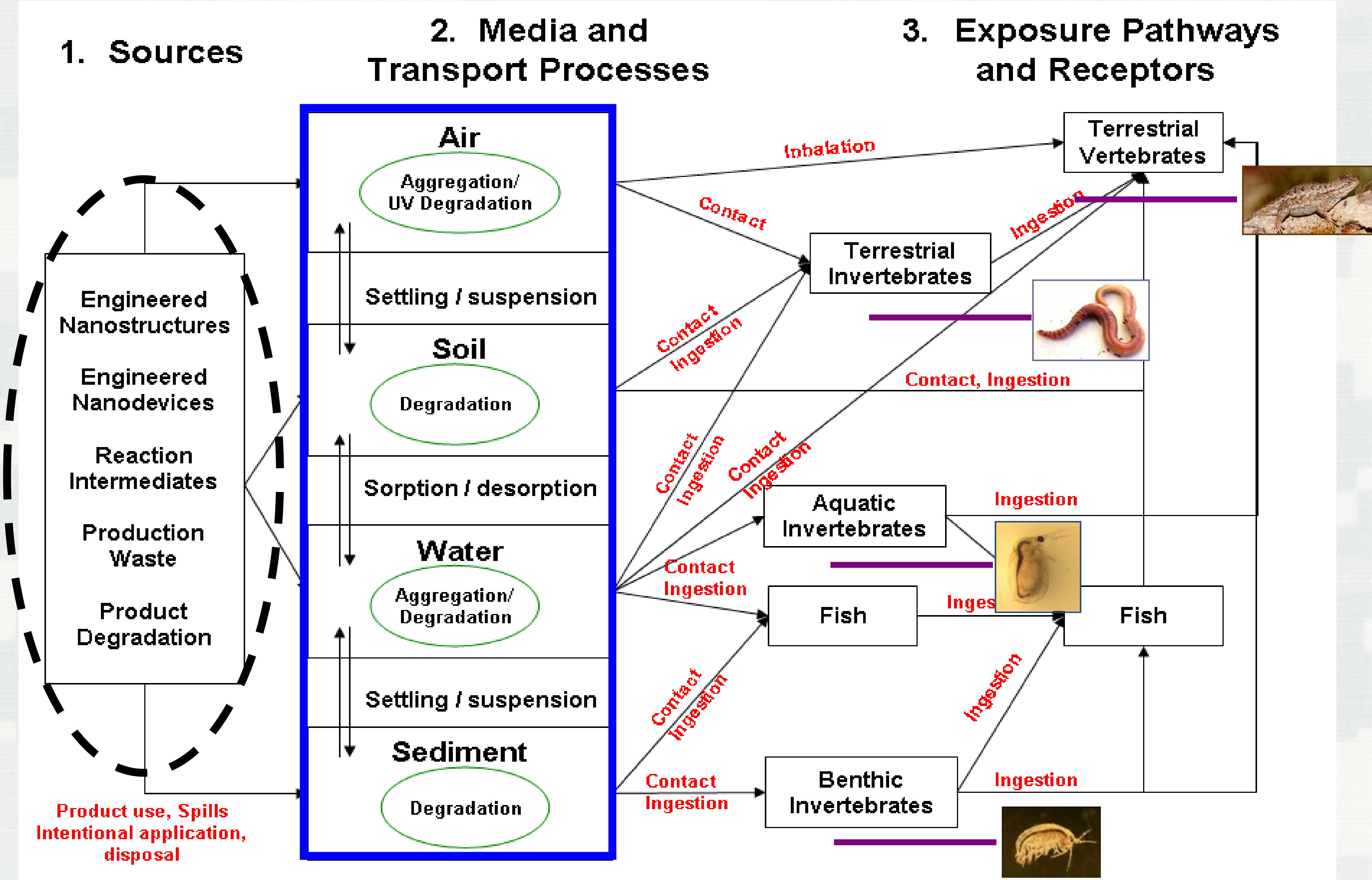


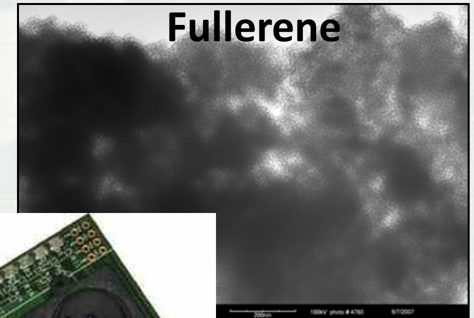



Interdisciplinary team of experts in fields of materiel science, geology, soil science, toxicology, and computational chemistry

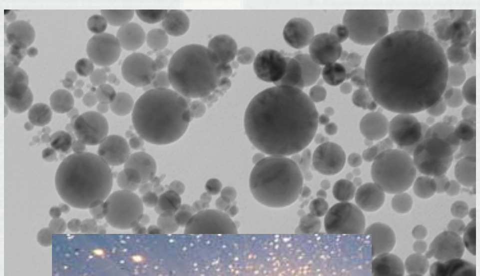
Conceptual Model: Environmental Impact of Nanomaterials



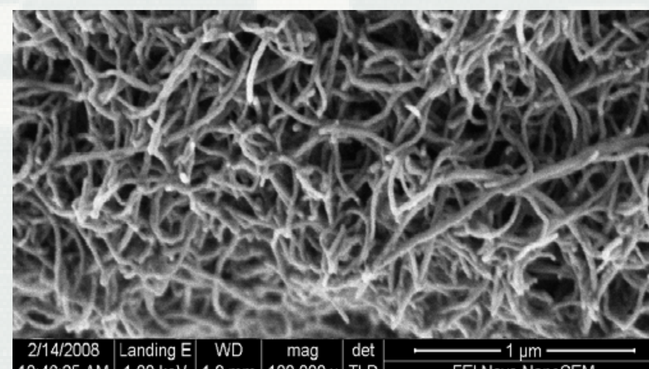
Current Research Materials



Aluminum Oxide (Al_2O_3)



MWCNT



Nano Aluminum

Potential military uses:

•Oxidizer in energetics / propellants

- High energy release during oxidation to Al_2O_3

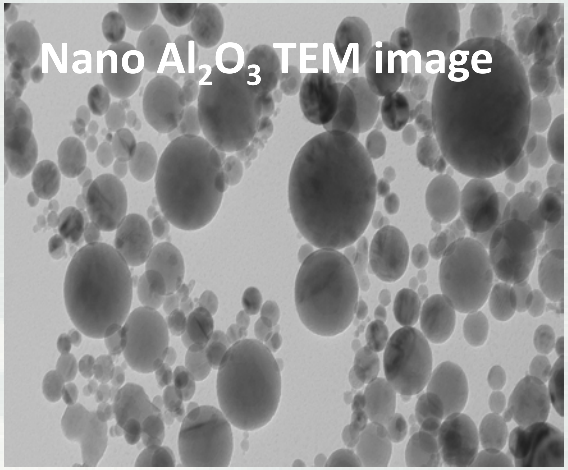
-Diesel fuel additive (Tyagi et al. 2008) in rocket propulsion

•Increase burning rate, heat, and energy density

- lower ignition time

-reduces ignition time and temperature by two-fold

(Armstrong et al. 2003; Meda et al. 2007).



Industrial uses:

•Coatings

•Abrasives

• Polishing of optics and jewelry

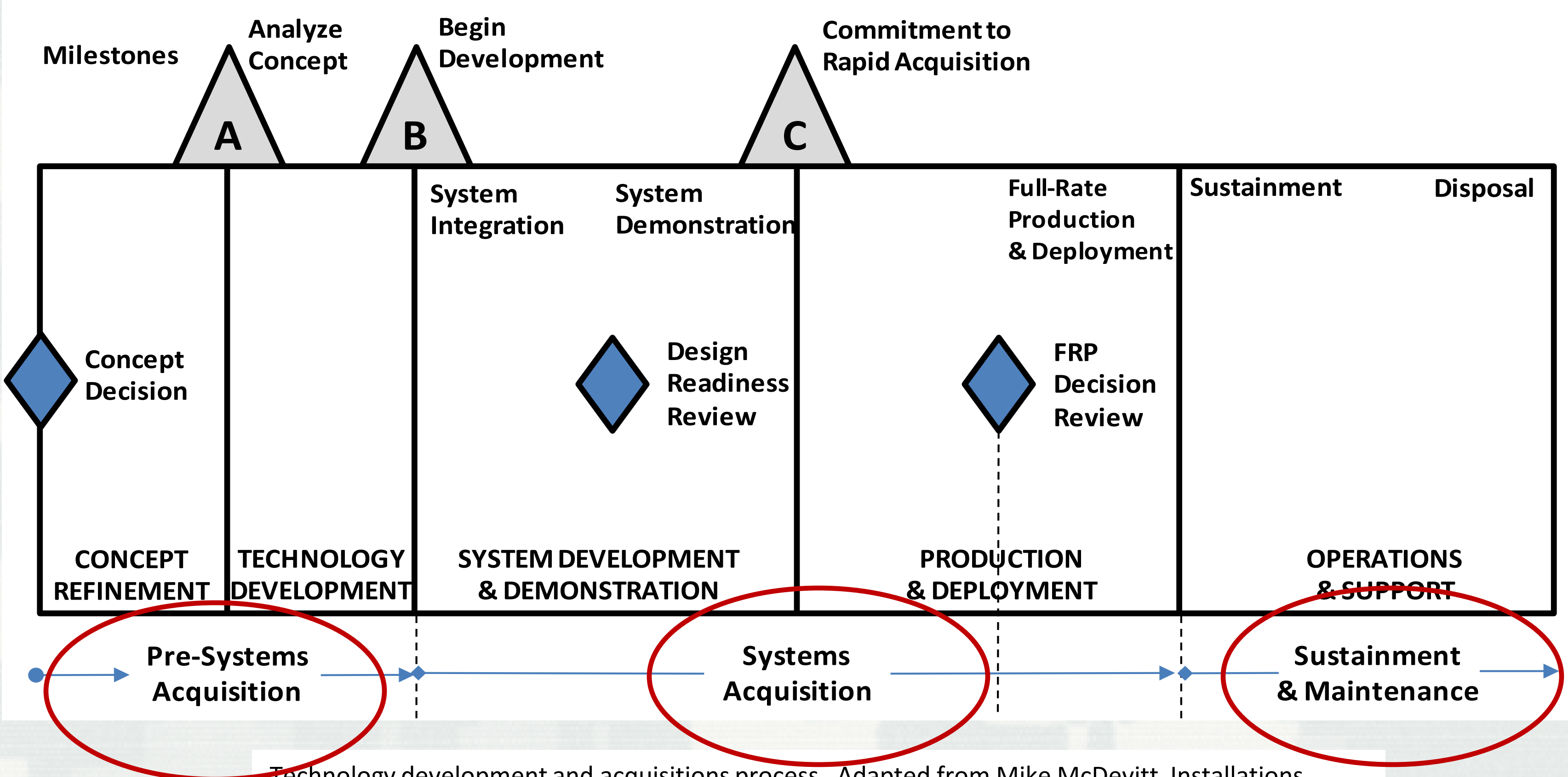
All create potential sources of release for nano Al_2O_3 to environment

Assessing Impact of Nano Al_2O_3

- Need to assess both human and environmental impact
- Arising regulatory requirements could limit military use if not extensively characterized; i.e. European Union on the Registration, evaluation, Authorization and Restriction of Chemical substances (REACH)
- Aim to follow a comprehensive environmental assessment (CEA); provides holistic outlook on material life cycle and environmental risk

- New DoD technologies undergo an technology development and acquisitions process; track R&D, production, deployment, use and disposal

Stages of Acquisition Process Benefiting from Environmental Hazard Assessment

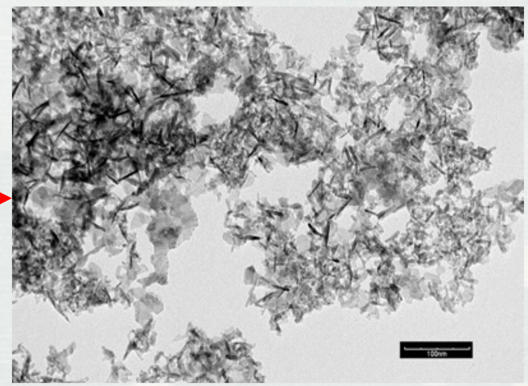


Technology development and acquisitions process. Adapted from Mike McDevitt, Installations Management Command

Environmental Risk of Nano Al_2O_3

- What are the potential environmental risk of nano Al_2O_3 particle release?
- Due to use of material over land ranges and potential for water runoff and soil mobility, how do factors such as fate, transport in terrestrial and aquatic environments affect organisms?

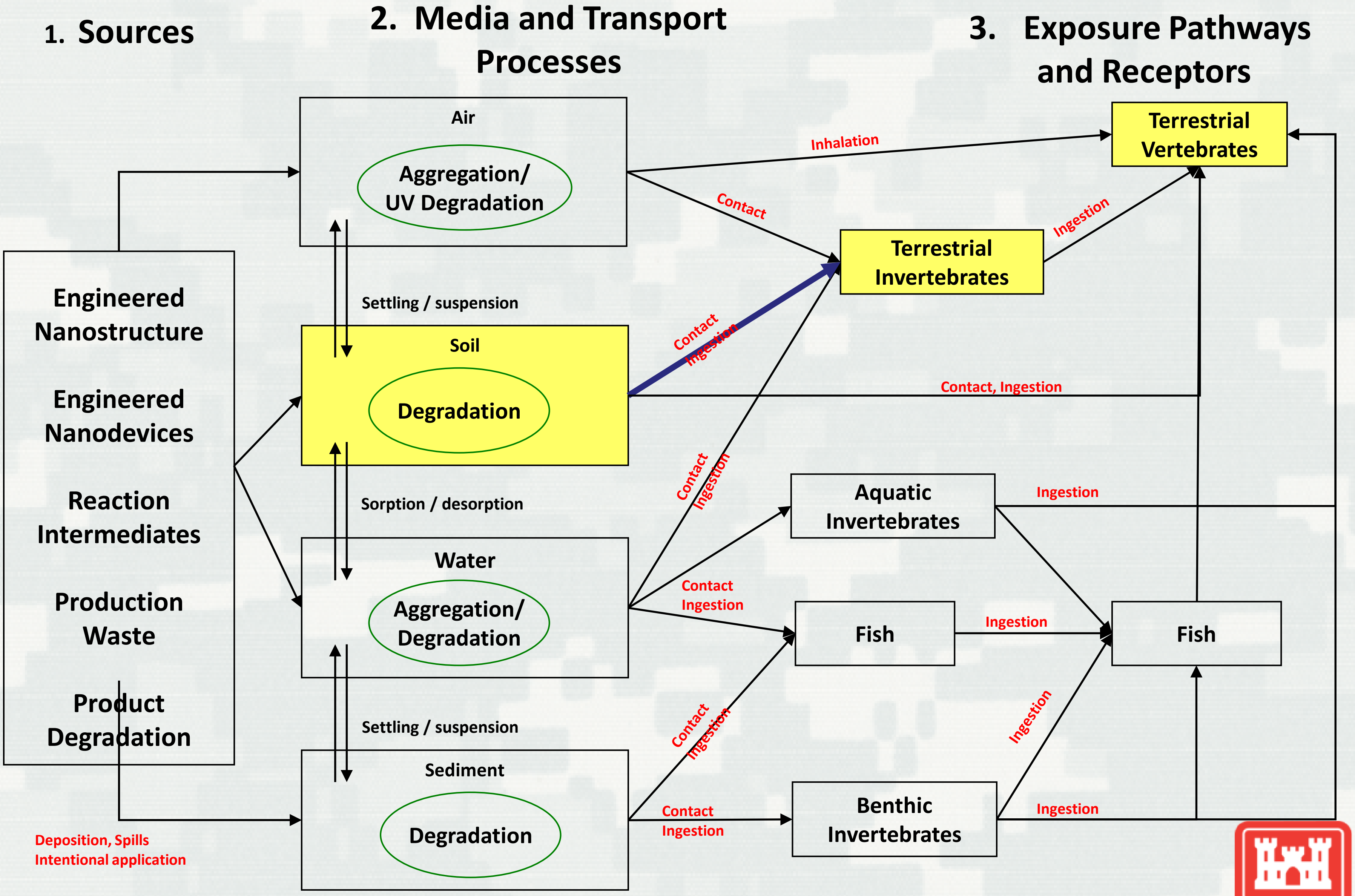
Use in additives/explosives/ propellants



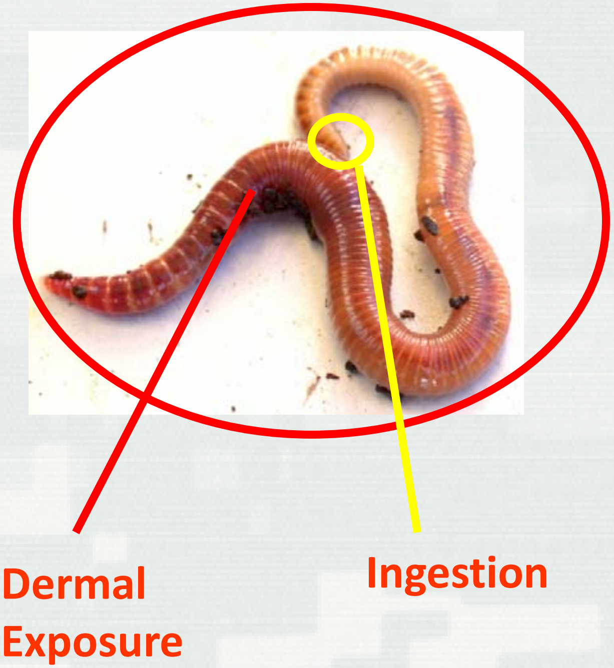
Nano Al_2O_3 particles dispersed

Potential impact on terrestrial/aquatic organisms

Case Study: Nano Al_2O_3 in Terrestrial Systems



Model Species: *Eisenia fetida*



•**Habitat:** upper layers of soil

•**Ecological impact**: nutrient cycling and food source for larger predators

•**Rationale for exposure of *Eisenia fetida* to nano Al_2O_3:**

•Earthworms imbed in soils → potential for whole body exposure

•Earthworms exhibit toxicity response to certain metals

•Potential for bioaccumulation through ingestion and dermal uptake

Experimental Approach

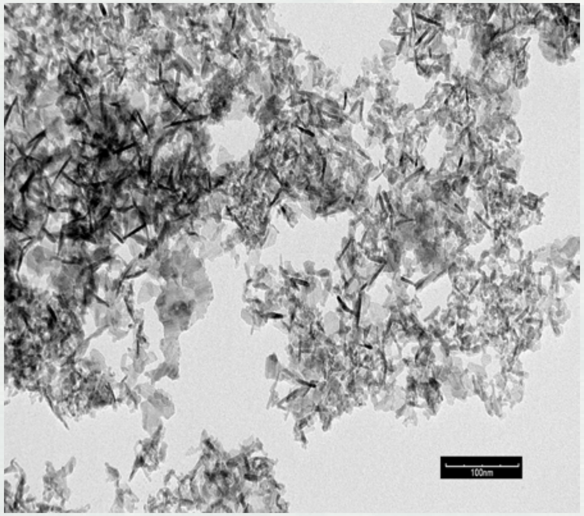
28-Day Sub-Chronic Bioaccumulation/ Toxicity Study:

E. fetida exposed to a nano and micron-sized Al_2O_3 treated soil

Soil Avoidance Bioassay:

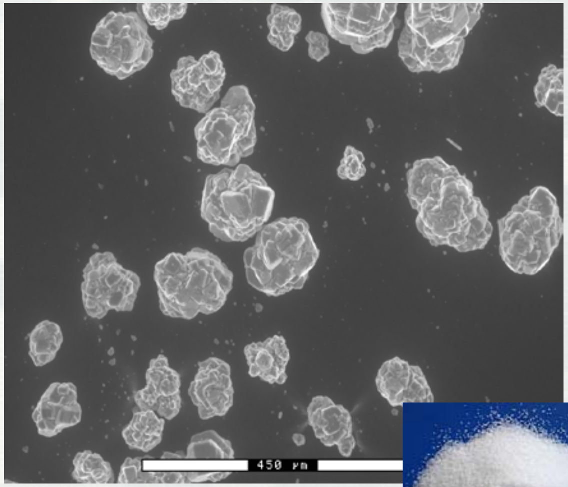
48-hour soil avoidance study exposing earthworms to nano and micron-sized Al_2O_3 amended soils utilizing a soil avoidance wheel.

Nano Al_2O_3 Characterization



Nano Al_2O_3

- TEM Image
- Particles 1->100nm present, manufacturer size 11nm
- Spherical particles and rods present
- DLS- bimodal populations
- Zeta potential- not stable in water



Micron-sized Al_2O_3 SEM Image

- Consistent with manufacturer statement, Al_2O_3 particles between 50-200 µm

Sub-Chronic Bioaccumulation Toxicity Study: Soil Exposures

Earthworms depurated 24-hours
Adults 0.3-0.6 g

10 added per treatment

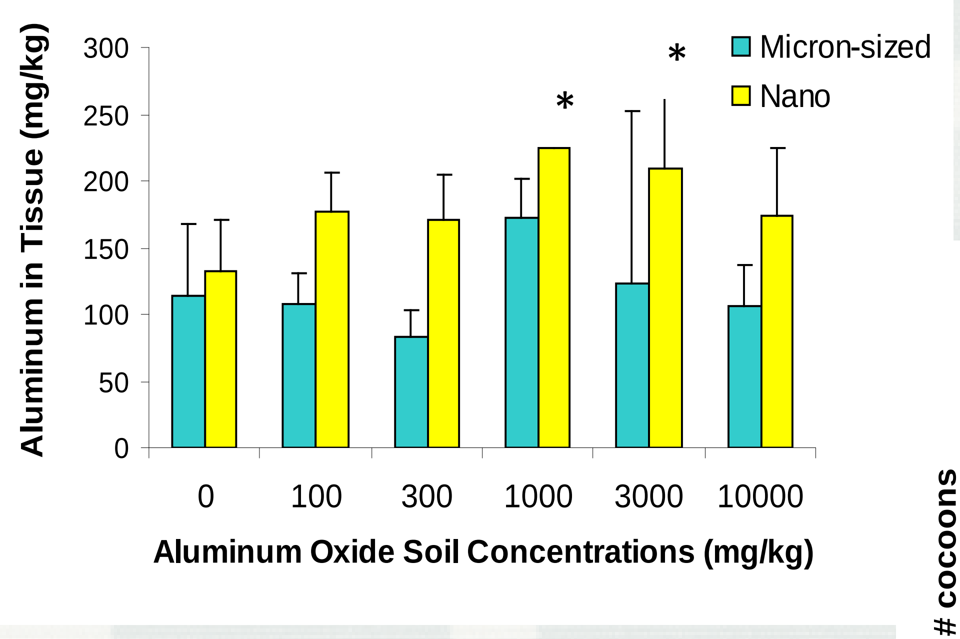
Test conducted 28-days at 22°C, 80% humidity, continuous light

Endpoints assessed: bioaccumulation, toxicity, growth, reproduction

Treatments 0-10,000 mg/kg

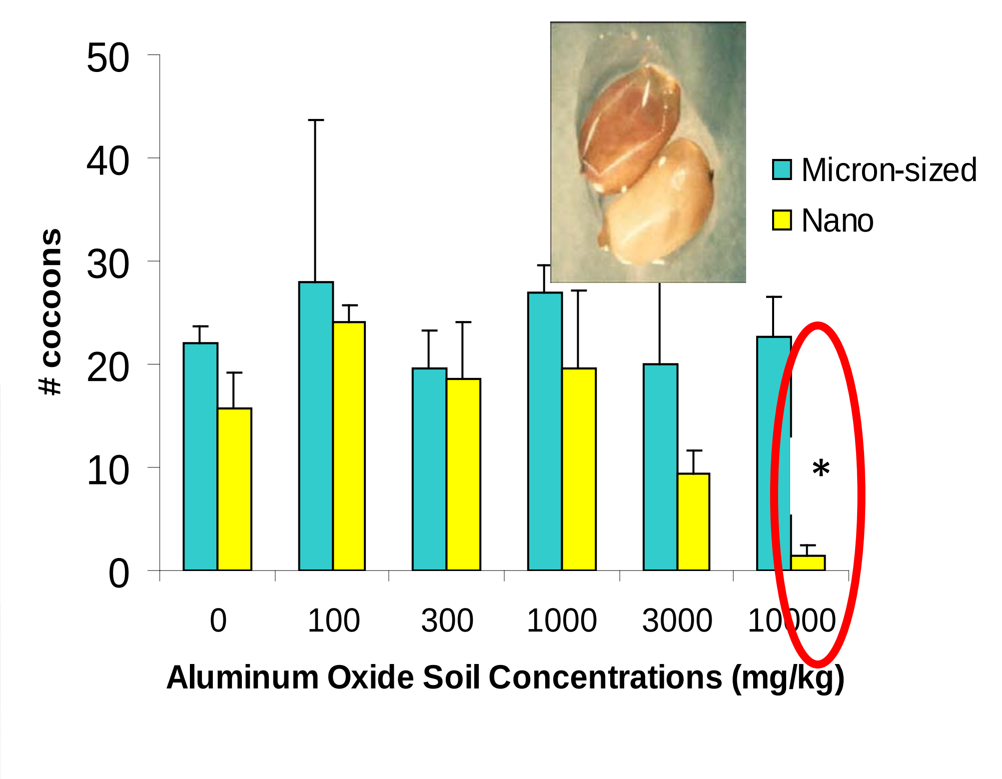
Results

Bioaccumulation

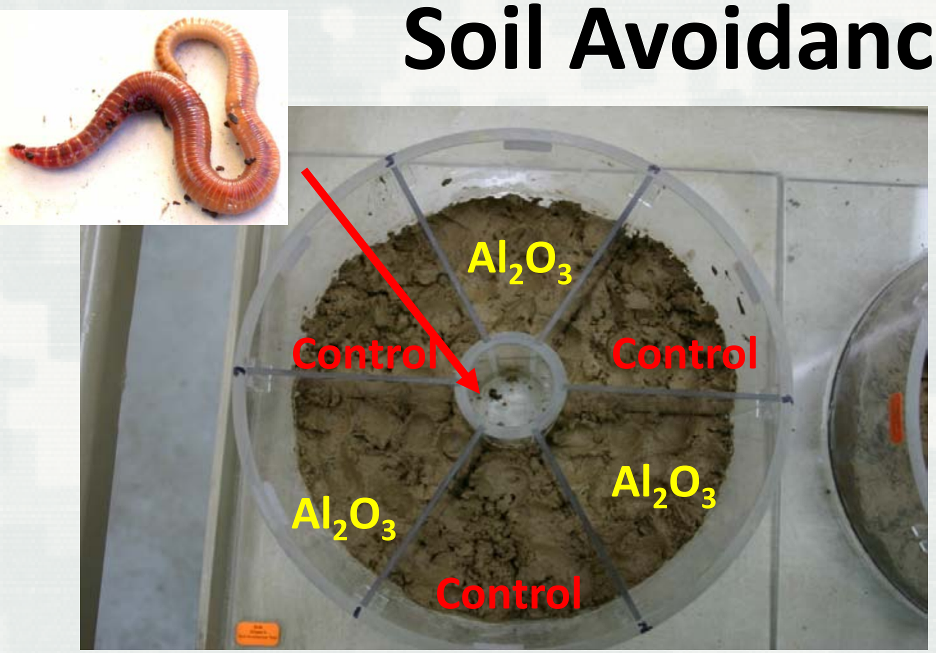


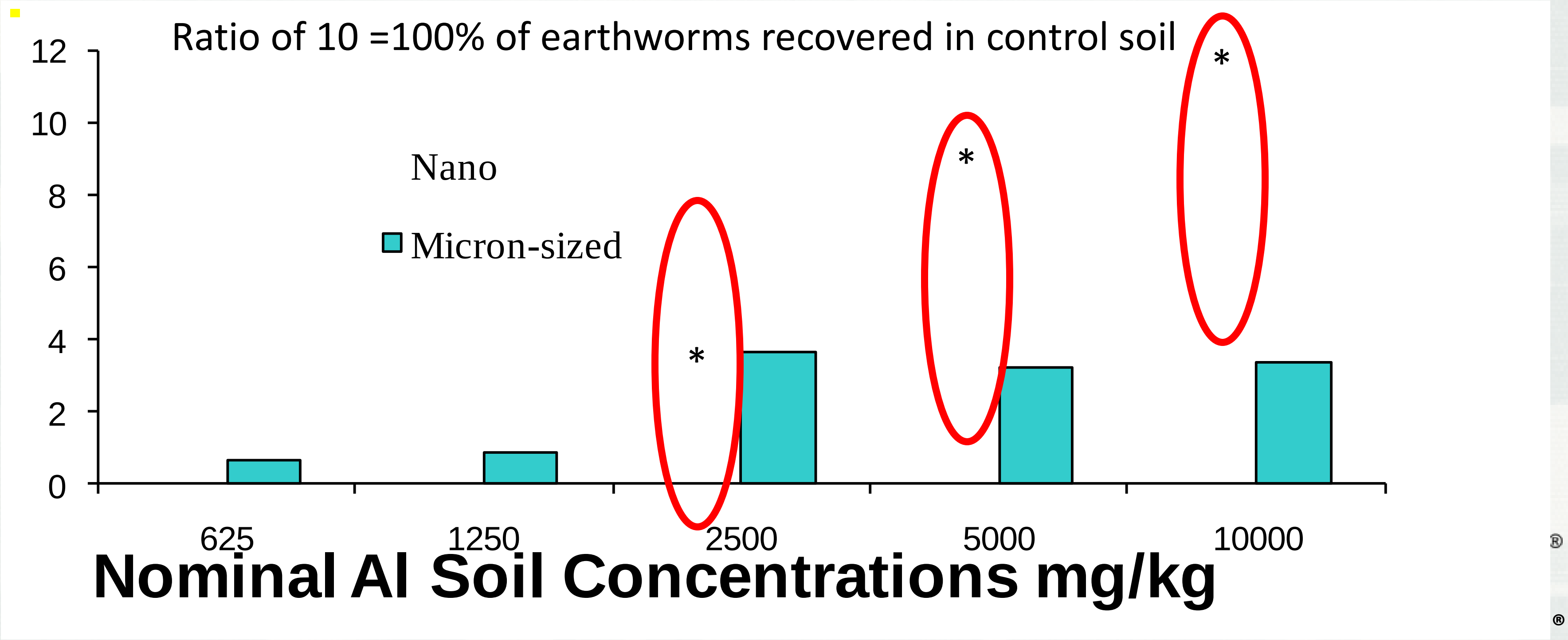
Reproduction

100% survival, but reproductive toxicity observed



Soil Avoidance Results: 48-h



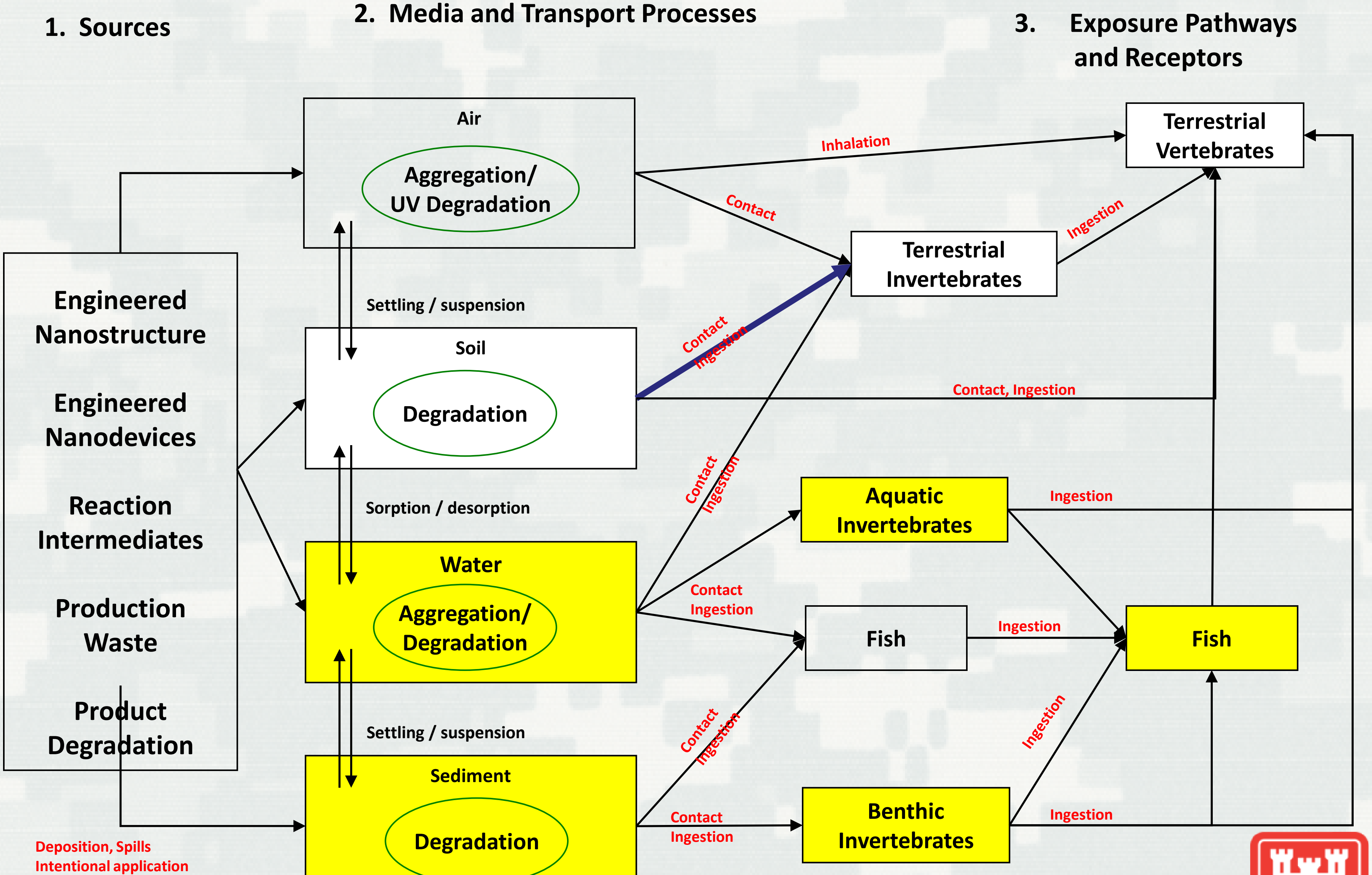


Discussion: Terrestrial Impact of Nano Al_2O_3

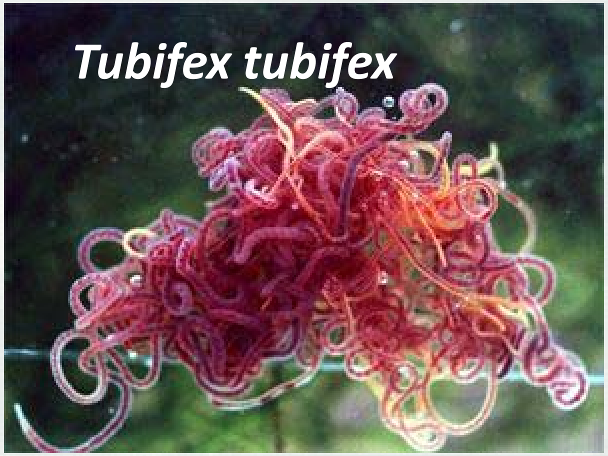
- Nano Al_2O_3 may cause negative impacts in terrestrial invertebrate populations such as reduced reproduction and habitat
- Negative impacts only observed at > 3,000 mg/kg nano Al_2O_3
- Concentrations where effect is observed is unlikely to be found in the environment except under extreme circumstances

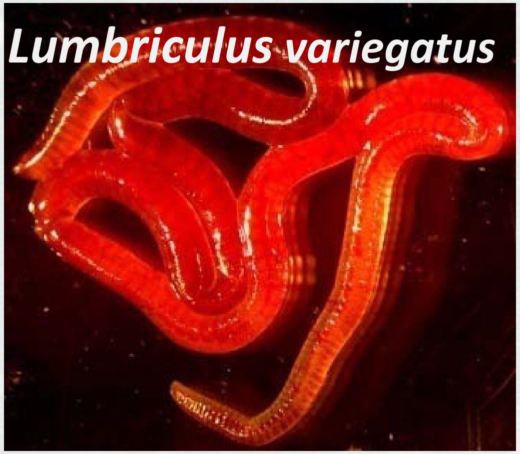
Coleman et al. 2010. Assessing the fate and effects of nano aluminum oxide in terrestrial earthworm, *Eisenia fetida*. Environ. Toxicol. Chem.

Case Study: Nano Al_2O_3 in Aquatic systems

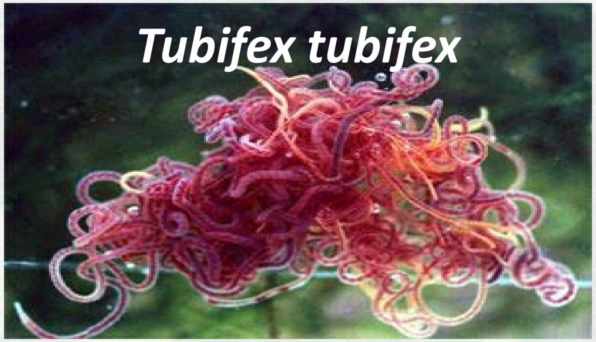


Organisms Tested

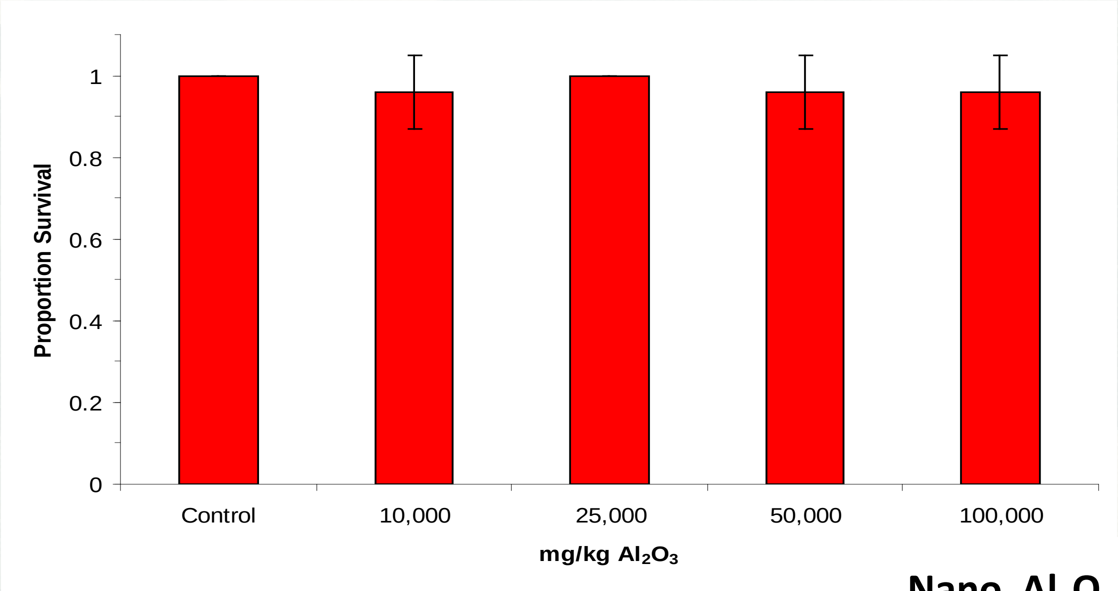




Nano Al_2O_3 Sediment Tests - Survival

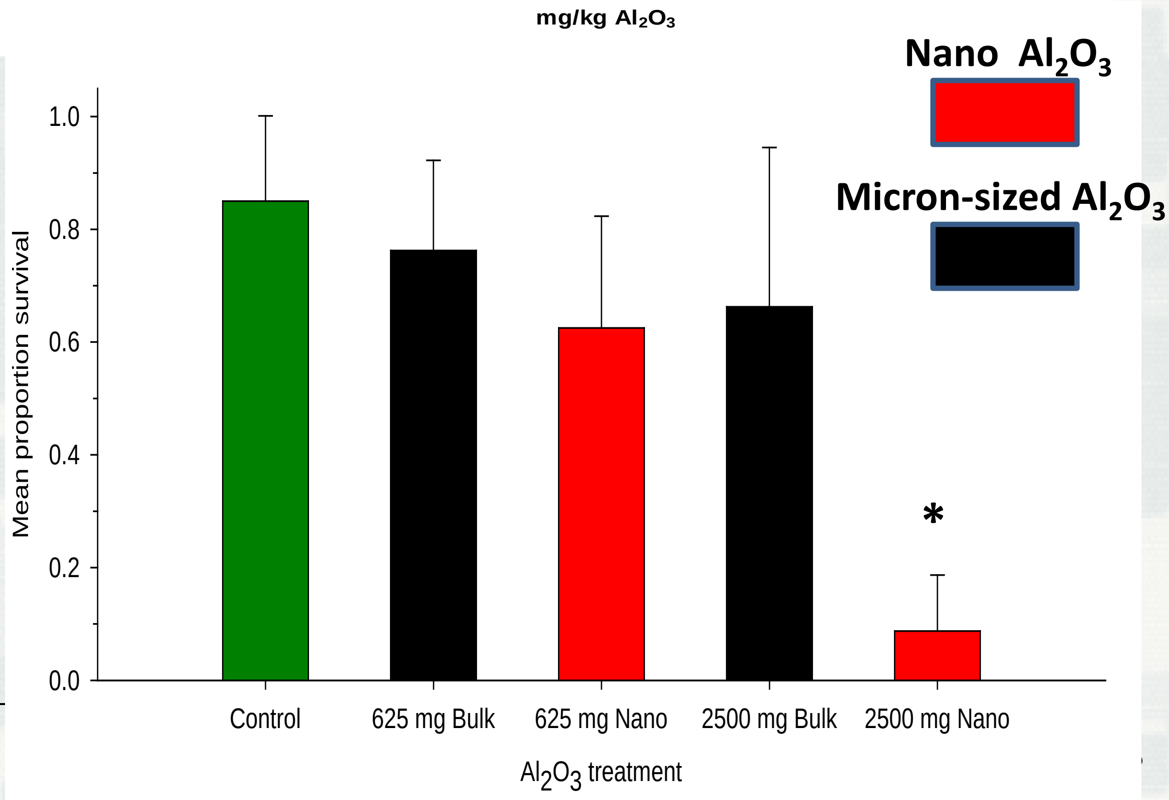


Survival up to 100,000 mg/kg

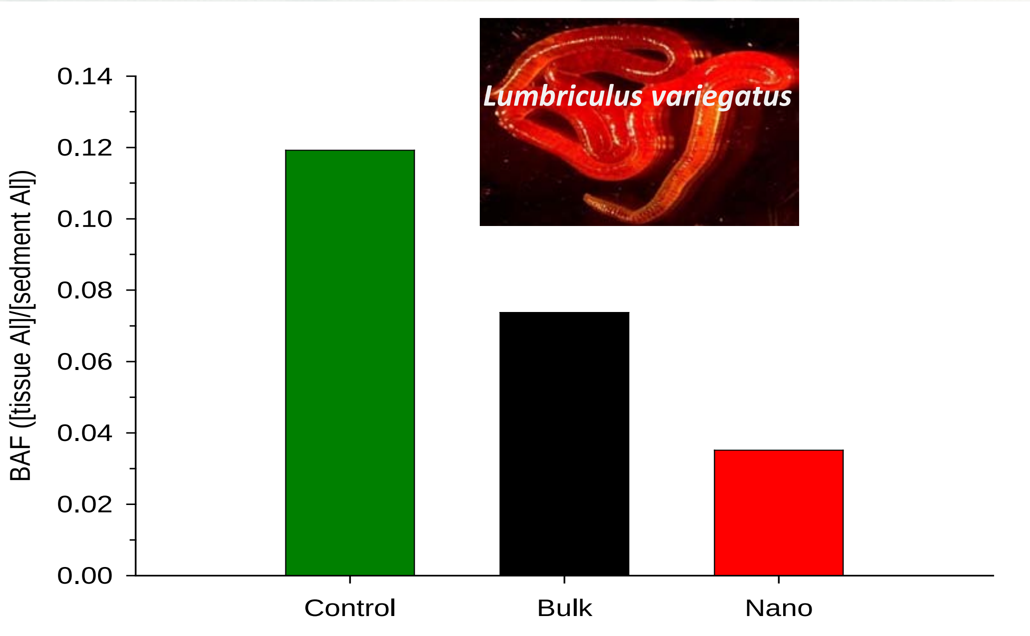


Hyalella azteca

Significant mortality at 2500 mg/kg in sediment



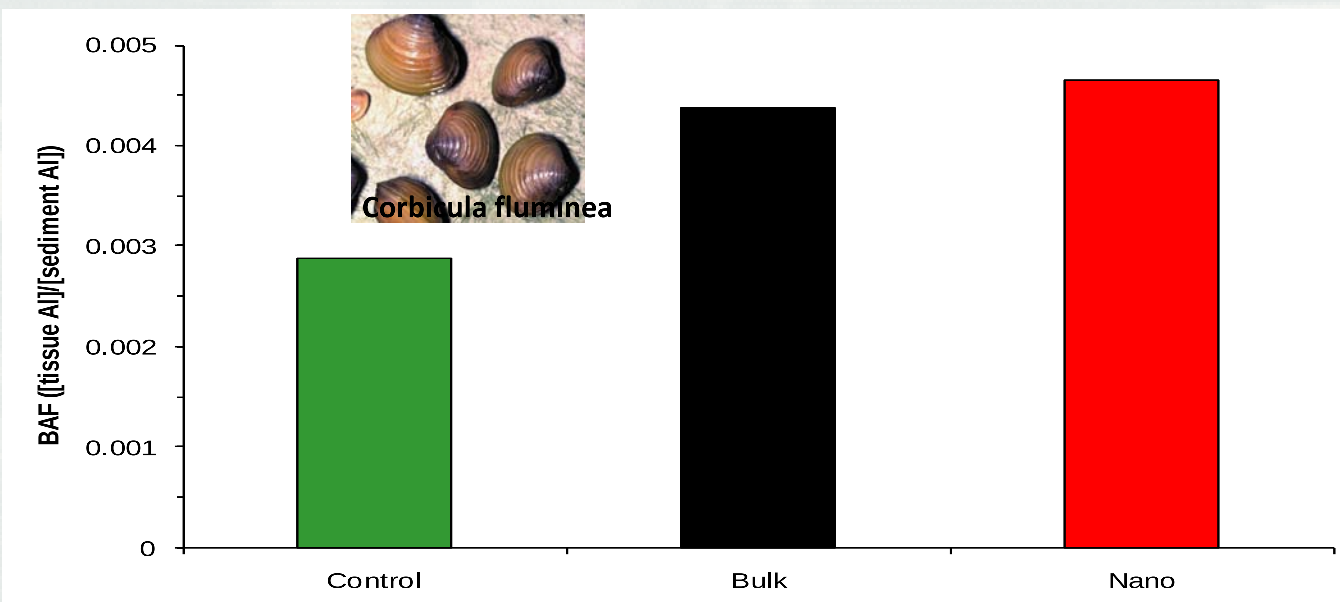
28-d Nano Al_2O_3 Sediment Bioaccumulation



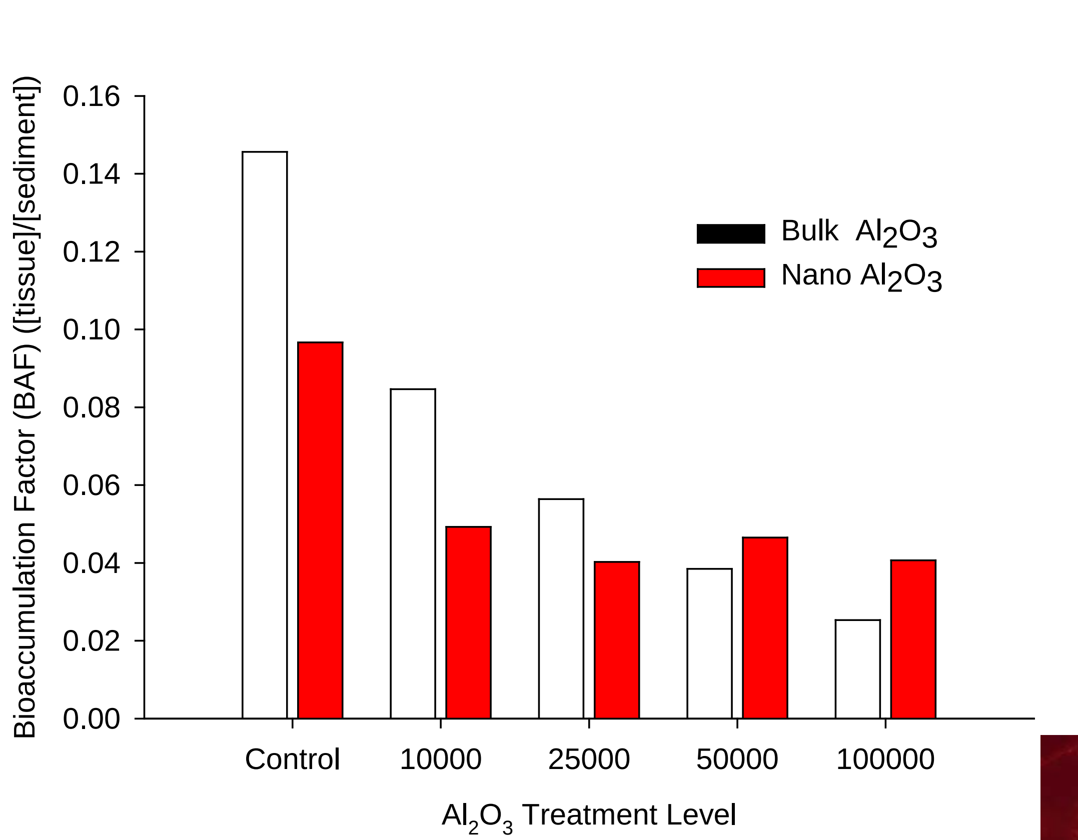
Bioaccumulation factor (BAF)- ratio of the contaminant in an organism to concentration in environment at steady state

Treatment

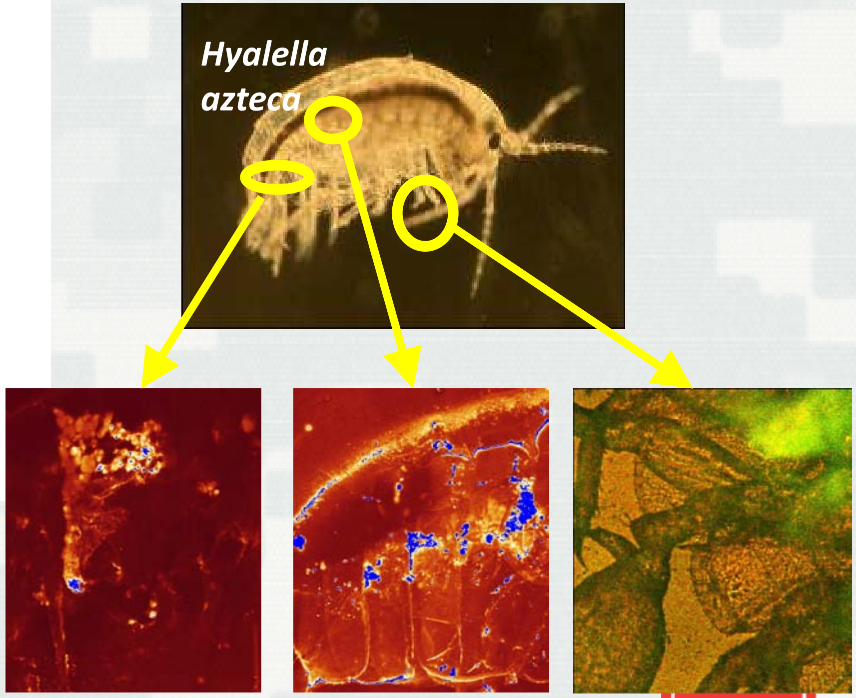
25g/kg Al_2O_3



Hyalella azteca 10-d - Bioaccumulation



Confocal Image

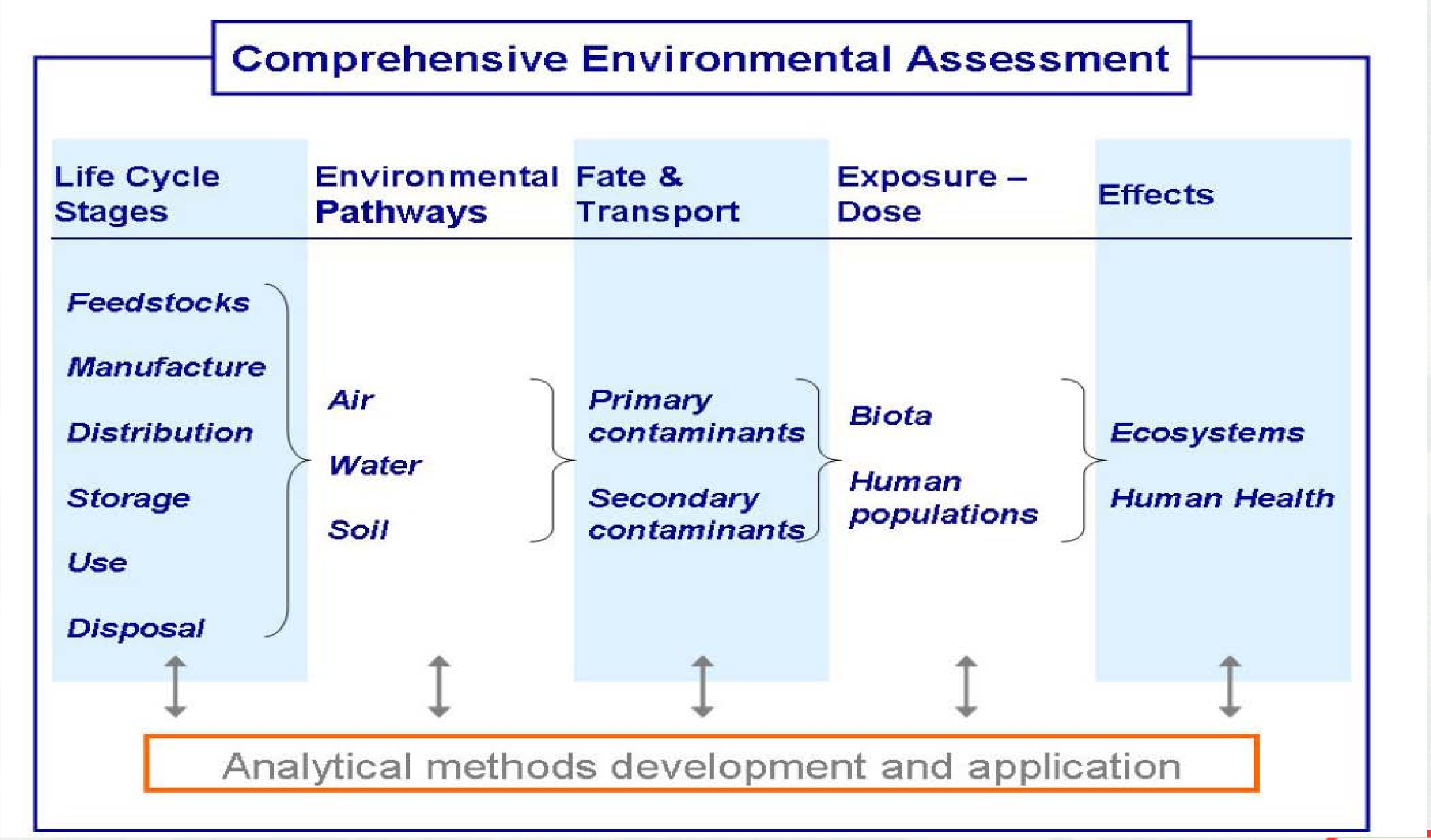


Discussion –Aquatic Exposures

- No toxicity observed to *Tubifex*
- Nano more toxic than bulk to *Hyalella*
- BSAFs similar for nano and bulk in *Hyalella* and *Corbicula* bioaccumulation studies
- BSAF for bulk higher than nano in *Lumbriculus*
- However, significant effects observed only at high, environmentally unrealistic concentrations
- Therefore, our results support a finding of low environmental risk of nano Al_2O_3 to benthic and terrestrial invertebrates

Stanley et al 2010. Sediment toxicity and bioaccumulation of nano and micron-sized aluminum oxide

Steps Forward: Incorporate into Comprehensive Environmental Assessment (CEA)



Adapted from Davis, 2007

To learn more about the nano CEA:

 # 12667 A Comprehensive Environmental Assessment Approach to Making Informed Decisions about Engineered Nano Particles

Dr. David Johnson

Thursday, 2:30

Room 278

US Army Engineer Environmental Laboratory, Vicksburg, MS, USA

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601-634-3976

http://el.erdc.usace.army.mil/nano/index.html